

Minimizing Micro-cracks in Solar Cell Interconnection During Manual Soldering

Solar cell substrates are delicate. The manual soldering process applies stress to the material which can cause micro-cracks to form. This article identifies the requirements and equipment needed to reduce the micro-cracking during solar cell assembly.



Photovoltaic Cell (PV) Module Assembly

There are two soldering process steps used to assemble a PV module; the first step is photovoltaic cell interconnection, called stringing or tabbing, and the second step, PV module assembly, is called bussing.

Initially, the cells are electrically connected using tinned copper ribbon which is typically 2mm wide. The solder-coated ribbon is dipped into, or sprayed with, flux. The flux is used to promote wetting and remove oxides from the surface of the ribbon. A point of contact between the collector grid (substrate) and the ribbon is formed by screen printing a metallization paste to the substrate. The tabbing ribbon provides all the solder required to form a bond between the ribbon and the substrate.

Next, individual PV cells are attached in series forming a column by reflow soldering and precisely placed onto a glass substrate. Six to ten rows of cells are then "bussed" together using 5mm wide bus ribbon to create the collector grid. Bussing together the columns of solar cells is performed by hand using a soldering iron. The need to reduce PV manufacturing costs is driving a steady reduction in wafer and cell thicknesses. As a result, the soldering process has become more challenging because the thinner cells are even more sensitive to thermally induced micro-cracking.

During the manual soldering operation, differential thermal expansion of the copper and the silicon elements can occur at temperatures greater than 300°C. This differential can result in the formation of micro-cracks that may not be detected during the manufacturing process and result in a less than expected field lifespan. The need for precise time and temperature control is additionally critical by the inter-metallic layer requirement of within 1-2µm that must be created during the solder joint formation.

Process Control and Defect Detection

A process window to reduce cell damage and consistently produce good inter-metallic bonds between the ribbon and the solar cells must be identified and maintained.

A controlled time and temperature are needed at the solder joint to form an inter-metallic layer of 1-2 μm . Precise control of time and temperature reduce the possibility of forming micro-cracks in the substrate

Damage to the crystalline silicon can be detected by conducting a peel test according to conventional soldering interconnect joint specifications.

Peel force values up to 6 Newton (1.1 pounds of force), which is within IPC/EIA J-STD-001 for a conventional solder interconnection joint, should not damage the interconnection. After peeling off the ribbons, the tabbing ribbon remains in partial contact with the metallized substrate of the solar cell (Figures 1 & 2).

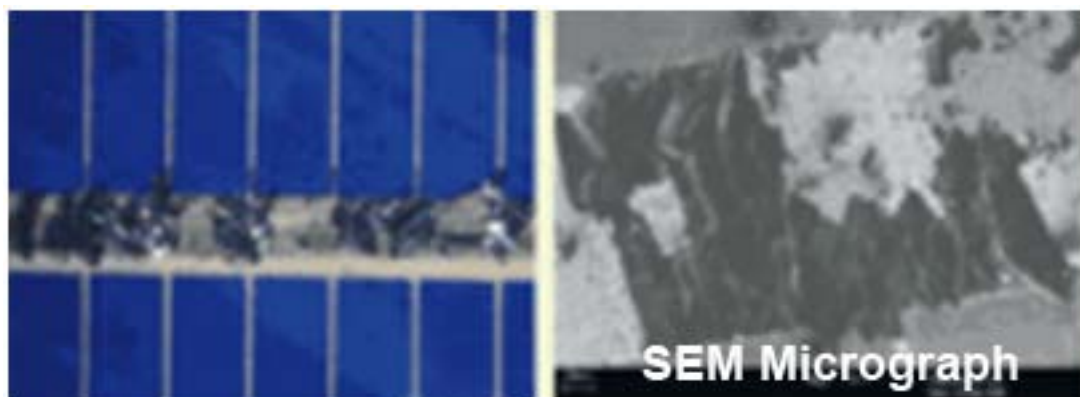
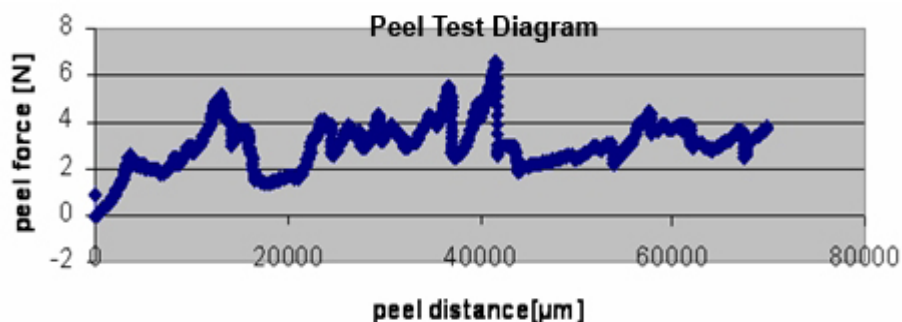


Figure 1, above: Conventional solder joint after peel-test using optical and SEM micrographs

Figure 2, below: Peel test diagram; Pb-free solder interconnection on standard metallization. The variation in force results from the manual soldering process.



Suitable Solder Types

There are two suitable solder alloys utilized for solar cell soldering application; Sn96Ag4 with a melting point of 221°C, or bismuth containing Bi58Sn42 with a melting point of 138°C. Proper soldering will result in an intermetallic layer that is within 1- 2µm (Figures 4 & 5, below).

The soldering temperature must be reduced to a minimum so that the solar cells will not be subjected to mechanical or thermal stresses from the hand soldering process.

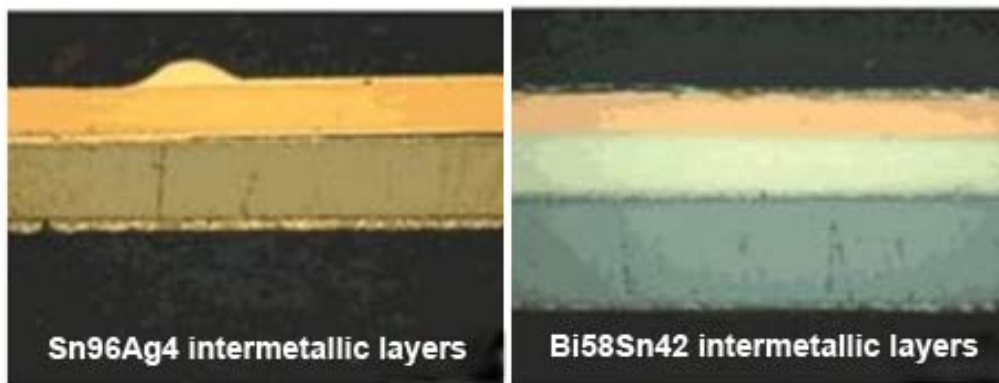


Figure 4: Sn96Ag4

Figure 5: Bi58n42

SmartHeat®

A thermal technology exists that will produce and maintain a specific, self-regulated temperature with a heater that requires no calibration and responds directly to thermal loads. The patented SmartHeat® Technology consists of a high frequency alternating current (AC) power supply and a self regulating heating element. The heater utilizes the electrical and metallurgical characteristics of two different metals; copper, which is a material with high electrical conductivity, and a magnetic material with high resistivity.

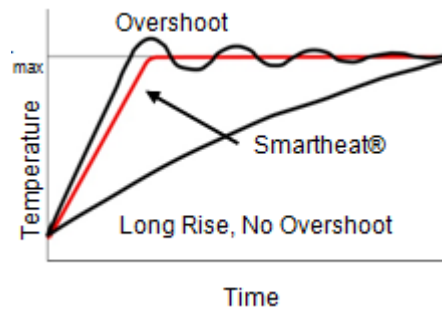
When the heating element is energized by the high frequency alternating current (AC) power source, the current will automatically begin to flow thru the conductive copper core of the heater. However, as the AC current continues to flow, a physical phenomenon known as the “Skin Effect” occurs, and the current flow is directed to the skin of the heater assembly, driving the majority of the current thru the high resistance magnetic layer and causing rapid heating.

As the outer layer reaches a particular temperature (which is controlled by its heater alloy formula), it loses its magnetic properties. This “Curie point” temperature is

when the skin effect begins to decrease, again permitting the current back into the conductive core of the heater and repeating the cycle.

SmartHeat® technology is thus an inherently temperature stable form of resistance heating. Because of this inherent stability, it eliminates the need for external temperature control devices, and is characterized by:

- Temperature self-regulation
- No temperature overshoot
- Fast thermal response and recovery
- High watt density direct power



Experiments were performed using the OKI International SmartHeat PS-900 soldering system to evaluate its suitability for solar cell applications. Custom designed STV-DRH40 hoof tip geometry was chosen to optimize the power delivered to the solder joint, thus providing high performance efficiency with increased tip life. The Temperature-sensitive “T” series heater was chosen to ensure low temperature soldering and thus to minimize thermally

induced stresses on the surface of the solar cells. In order to minimize thermally induced damage of the solar cells due to micro-cracking, it is critical to maintain the solder joint below 300°C at all times during the soldering operation. This was demonstrated by using the PS-900 system with the STV-DRH40 tip to solder a twelve inch strip of 0.4 mm ribbon onto the surface of a solar cell. The solder ribbon was placed on top of five thermocouples positioned three inches apart and the heated soldering tip was moved along the surface of the ribbon. Results show that by moving the heated soldering tip at an approximate rate of one inch per second, solder reflows efficiently at the ribbon and results in the formation of an inter-metallic bond of within 1-2µm. Moreover, since the heat is delivered directly to the solder joint, the temperature profile measured at the ribbon is observed to be uniform and follows a repeatable curve below 300°C with no thermal overshoot. The quick response of the SmartHeat PS-900 system combined with the lower “T” series tip temperatures helps minimize the thermal gradients and thus maintains high yields and module reliability for the solar cell application.

In conclusion, a variable power output power supply combined with a tip designed specifically for the application will measurably reduce the potential for cell damage. By applying only the thermal energy required to form a good inter-metallic bond between the ribbon and the solar cell, the SmartHeat® system will operate within a much smaller process window.